Insights into the distribution and migratory movements of the Kemp's ridley sea turtle. **Nancy B. Thompson, Southeast Fisheries Science Center, Miami, FL 33149 and Rene M. Marquez, Instituto de Pesca, Manzanillo, Mexico**

Abstract

Data on dead Kemp's ridley turtles have been collected since 1980 through both a voluntary and dedicated sampling of the U.S. Atlantic coast. These data are entered into the central Sea Turtle Stranding and Salvage Network (STSSN) data base at the Miami Laboratory of the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC). The STSSN includes all of the eighteen U.S. Atlantic coastal states. The information collected over the past ten years on turtles includes species identification, either straight and/or curved carapace lengths and sex depending on the condition of the carcass. A total of 1,678 Kemp's ridley turtles have been reported to the STSSN, which represents 9.7% of the total 17,257 turtles reported over this ten year period. Of these, 166 (9.8%) were accompanied with both straight and curved carapace lengths. These 166 turtles were used to derive a statistically significant relationship between straight and curved length which was then used to convert curved to straight length. A total of 1,678 turtles with straight (measured or converted) carapace length measurements were used to develop regional size frequency distributions. Regions were defined in the Gulf of Mexico as western, northern, and eastern and within the remainder of the U.S. Atlantic seaboard as southeastern and northeastern. An interesting result of these frequency distributions is the secondary peak in numbers of adults within the Gulf of Mexico and relative lack of adults along the eastern seaboard. This suggests that some turtles in waters off the U.S. east coast do return to the Gulf of Mexico "breeding population". Sex ratios were also developed from a total of 225 Kemp's ridleys identified as either female or male. The female:male values ranged from 1:2 in the western Gulf in the winter, to 6:1 in the eastern Gulf in the spring. Remarkably, most female:male values stratified by season and region were either 1:1 or 2:1, although sample sizes were generally very small.

Introduction

Information on dead turtles that wash-up on the U.S. Atlantic coast has been collected and archived through the Sea Turtle Stranding and Salvage Network (STSSN) of the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC) since 1980. All five species found within U.S. waters are represented within this data base. While the most consistent information included on these records includes species identification, some measurement of carapace length, either over the curve or straight line, condition and disposition of the carcass, and location and date. When possible sex is identified either through necropsy or from analyzing blood hormones. To our knowledge, this assemblage represents the largest data base in the United States on this relatively rare species.

This unique data base has allowed us the privilege of examining the differential size and sex distributions of this species stratified both temporally and spatially. There have been several recent papers that describe the size frequency distributions within specific waters but none are synoptic for the entire U.S. range of this species (Henwood and Ogren 1987; Crouse 1988; Danton and Prescott 1988; Heinly et al 1988; Plotkin and

Amos 1988; Epperly and Veishlow 1989; Rudloe et al 1989; Schroeder and Maley 1989; Standora et al 1989). This lack of a continuous data base throughout this species U.S. range has provided the basis of the debate on the continuity of the life cycle of this species for many years (Carr 1957, 1963, 1980; Pritchard 1969, 1989a, 1989b; Lazell,Jr. 1980; Fontaine et al. 1985; Byles 1989).

Even less information is available on the sex ratios of the wild population of this species throughout its U.S. range. A discussion at the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation, and Management focused on the sex ratio of hatchlings in the wild v captivity. It was concluded that in the absence of empirical data, the ratio which that was strived for in captive rearing should be a 1:1 female:male value (Caillouet,Jr. and Landry 1989). The results from estimating the sex ratios from the STSSN may not be representative of wild ratios, they are the first developed over the U.S. range.

Results of examining these synoptic data must be interpreted within the context of their limitations. As stated previously, these data do not provide information on the cause, location, or time of death. These data do provide significant circumstantial information on the differential distributions and possible movements of this species throughout its U.S. range.

Materials and Methods

The STSSN was initiated by NMFS in 1980 as a network of volunteers dedicated to obtaining data on dead turtles that washed up on the coast. Data are directed to a NMFS appointed state coordinator for verification when possible. These data are then received by the SEFSC STSSN Coordinator for inclusion in the Miami Laboratory STSSN Data Base. The implementation and workings of this network are described by Schroeder (1989). In 1987, some areas within the existing network were designated for systematic sampling to provide for the estimation of an annual index for mortality which would be representative on a regional basis (Thompson and Martinez 1990)[1]. The STSSN currently includes two distinct data bases; one derived from voluntary participation and, one derived from systematic sampling. Because of this disparity of data source, sampling effort is not standardized over the period 1980 through 1989 over all eighteen coastal Atlantic states.

Because of the status of this species, many state coordinators and the STSSN Coordinator often require some type of verification on the species identification and data accompanying these reports. Therefore, we are confident that these turtles are proper-

1 Thompson, N.B. and A. Martinez. 1990. Preliminary results of sytematic sampling for stranded sea turtles in NMFS statistical zones 4-5, 17-21, and 28-32. NOAA/NMFS/SEFSC Miami Laboratory Contribution No. MIA-89/90-05.

ly identified as Kemp's ridleys and that both sex identification and carapace measurements are valid.

To facilitate the evaluation and comparison of seasonal movements, we classified each reported turtle by region, sub-region, and season. Seasons and regions were defined based on the relatively large scale continuity of sea surface temperature and habitat through the defined regions. While we recognize that the North Atlantic Ocean includes the Gulf of Mexico, regions were at a first level defined as the Gulf of Mexico, representing Texas through the Florida west coast, including the Florida Keys v. the Atlantic, from Maine to the Florida east coast. A second regional level was defined separately within the Gulf and Atlantic. The Western Gulf is defined as the Texas coast; the Northern Gulf includes the coasts of Louisiana, Mississippi, and Alabama; and the Eastern Gulf represents the Florida west coast, including the Florida Keys. In the Atlantic, the Southeastern Atlantic includes the Florida east coast through North Carolina, and the Northeastern Atlantic includes Virginia through Maine. These areas are referred to as sub-regions. Seasons were defined as: winter, January through March; spring, April through June; summer, July through September; and fall, October through December.

Turtles were further classified into life history stage based on the carapace length measurement reported. Straight line carapace length (SLCL) measurements from the field are preferable over curved length (CLCL) measurements because there is probably less chance of error and the magnitude of the error will be smaller. However, from a field logistics perspective, it is often difficult to have calipers on hand. Given that sufficient records are accompanied by both straight and curved lengths, a linear relationship between curved and straight length is feasible using a least squares linear regression. In this way, curved length measurements were converted to straight to allow for stage class apportionment. Measurements in inches are converted to the nearest one tenth of one centimeter. Stage classes were defined after the scheme of Marquez (1990) as: juvenile up to 30 cm SLCL; sub-adult from 30.1 cm to 55 cm SLCL; and adult from 55.1 cm and greater SLCL. Frequency distributions in 5 cm. increments were evaluated for trends within each stage class with a least square linear regression. These distributions were stratified by region and subregion; and season within a region.

State STSSN Coordinators over this period have made a special effort to verify gender identifications (W. Teas, personal communication 1990). Usually, the sex of an individual adult turtle is determined via visual examination of the tail and for sub-adult, juveniles, and hatchlings through histopathological examination of tissues or titering of blood hormones. Female to male sex ratios were determined and stratified and compared by region and season. Relative frequency distributions in 5 cm SLCL increments were developed for females and males.

Results and Discussion

Seasonal and Regional Distributions

A total of 1,678 Kemp's ridley turtles were reported to the STSSN, representing 9.8% of the total 17,257 turtles reported over the period 1980-1989. The distribution of these records over the ten year period is presented in Figure 1. About 25% of the total strandings occurred in 1986, while the fewest reports occurred in 1980. Since 1986, the fewest reported strandings occurred in 1989. Several factors interact to results in this distribution. First, sampling effort over the entire study area has probably increased, and certainly in 1987 with the advent of systematic sampling in selected areas. Secondly, the public may be more aware of species differences and Kemp's ridleys may be increasingly likely to be identified correctly by the public. Thirdly, these changes may also reflect an increase in the numbers of juvenile Kemp's ridleys in the water from the period 1980 through 1985 v 1986 through 1989 as a result of protective measures on the nesting beaches. Lastly, the increase in reported strandings over the past four years may reflect an increase in mortality rates. The extent that these factors have effected any increase or decrease in reported strandings over this period is unknown. However, if more juvenile turtles are in the water, this has not resulted in significant increases in the numbers of turtles nesting in Mexico (Marquez 1990; Thompson 1987). Thus, mortality must be high for the juvenile stages.

The distribution of turtle strandings stratified by region and season are presented in Figure 1. Overall reported strandings were relatively high from the spring through the fall. Within the Gulf, a peak in strandings occurred in the spring and reported strandings decreased as the seasons progressed. Within the Atlantic, reported strandings increased from the winter to a fall peak. These patterns in the Gulf and Atlantic explain the relatively high strandings throughout the entire area from the spring through the fall.

Seasonal distributions were examined on a sub-regional basis. Within the Gulf of Mexico, the Western Gulf demonstrated a pattern consistent with the overall Gulf with the peak occurring in the spring and reported strandings decreasing as the seasons progressed. This pattern is consistent with the observations Rabelais and Rabelais (1980) from strandings and sightings in southern Texas from 1976-1979.

In the Northern Gulf, the peak occurred in the summer, with relatively high strandings additionally in the spring. Very few strandings were reported in the winter. The most comprehensive report on the presence of Kemp's ridley turtles in Northern Gulf waters was completed by Fuller (1984) who noted that the peak in strandings along and sightings within Louisiana waters occurred from April through August. Fuller (1984) also stated her sampling method which included interviews with fishermen may have produced results biased by seasonal fishing effort. The STSSN data are probably biased by variable sampling effort and yet these results are consistent with the findings of Fuller (1984).

In the Eastern Gulf, peaks occurred in the spring and fall, with fewer reports in the summer and winter. Within the Eastern Gulf, the seasonal distribution was much lower for all seasons than the other two areas. Carr and Caldwell (1956) described the relative abundance of Kemp's ridleys as peaking from April through November (spring, summer and fall) from field work conducted off the Florida west coast in 1955. Ogren (1989) described the seasonal occurrence of Kemp's ridleys within waters of the Florida west coast as similar to that from Carr and Caldwell (1956), from May through November based on his own field observations from 1984-1987. The STSSN data base and Carr and Caldwell (1956) and Ogren (1989) agree on describing the seasonal abundance of this species along the Florida west coast.

Reported strandings increased from winter to a fall peak within the Atlantic. This was the pattern both in the southeast and the northeast. Lazell (1980) first reported on the frequent strandings of Kemp's ridleys in November and December within New England waters. The observations by Lazell (1980) were recently corroborated by Danton and Prescott (1988) for Cape Cod Bay waters from 1977 through 1987. The presence of Kemp's ridley turtles in the summer in Long Island, New York waters has been well documented (Morreale et al. 1989). Further south in Virginia water, Lutcavage and Musick (1985) reported that Kemp's ridleys were more abundant in June with a secondary peak in October.

Within the southeast, the same seasonal pattern emerges with a peak in the fall. Schroeder and Maley (1989) examined stranding data collected since 1980 for the northern Florida and Georgia. Their peak in reported strandings occurred in November, which is consistent with our results.

Seasonal distributions suggested by the STSSN data, support the findings from studies that do not rely on stranded turtles (cites). It appears that turtles in the northeast must move southward in the fall and winter which is corroborated by Lutcavage and Musick (1985) and Schroeder and Maley (1989). The movements north and south in the Atlantic suggest that the east coast of Florida may be particularly important to Kemp's ridleys in the fall and winter.

Size Frequency Distributions

A total of 166 records, representing 9.9% of the total 1,678, included both curved and straight carapace length measurements. Of these 166 turtles, none were from the period before 1987, 1 (.6%) was reported in 1987, 79 (47.6%) were from 1988, and 86 (51.8%) from 1989. A least squares linear regression was completed with the natural log of straight length dependent upon the natural log of curved length. The resultant linear relationship significant at p.01., is shown in Figure 3. The equation for this relationship is presented in Figure 3. This relationship was used to convert curved length measurements to estimated straight lengths for the remaining 1,512 turtles. A total of 1,678 turtles were included in the classification by SLCL and life history stage.

After much examination of these data, 10 cm increments were used to develop size frequency distributions (Figure 4). Turtles from 5 cm to 15 cm rapidly disappear from the data base suggesting that either these turtles rapidly disappear from the near shore habitat or are not detected or reported. The natural log of incremental frequency was plotted against size class interval (Fig. 4). Relative frequency distributions were plotted by region and sub-region. The sub-region curves are additive to allow for the comparison of the Gulf v. Atlantic (Fig.4). The trends in both the Gulf and the Atlantic are similar. Assuming that 1) sampling effort is not biased, 2) rapid decomposition does not eliminate small turtles from the sample, and 3) most strandings represent turtles from near shore and inshore waters, then, it appears that turtles are fully recruited into coastal benthic habitats by 30 cm. within the Atlantic and 25 cm. within the Gulf. This is consistent with site specific length frequency information both in the Gulf of Mexico (Liner 1954; Dobie et al. 1961; Sweat 1968; Rabelais and Rabelais 1980; Gunter 1981; Fuller 1984; Rudloe and Rudloe 1989) and the Atlantic (Carr 1952; Lazell 1980; Lutcavage and Musick 1985; Henwood and Ogren 1987; Crouse 1988; Danton and Prescott 1988; Schroeder and Maley 1989; Standora et al 1989).

On a sub-regional basis within the Gulf of Mexico, peaks in frequency occurred at the 35 cm midpoint within the Western and Eastern Gulf, and at the 25 through 35 cm classes in the Northern Gulf. The rate of decline through the larger size classes is more rapid in the Northern Gulf then the Western and Eastern Gulf suggesting that turtles in the Northern Gulf are more transitory than those in the Eastern and Western Gulf. All size classes were more likely represented in the Western Gulf and least likely within the Northern Gulf.

Stratification by size class demonstrated differential distributions within regions and between oceans. There were no reports for turtles in the northeast in the 55 cm class, while this size class is represented by a secondary peak in the southeast. The secondary peak in the northeast is in the 60 cm size class, with a decline in the frequency of turtles in this size class in the southeast. No turtles greater than 65 cm. were reported in the northeast, and no turtles greater than 70 cm were reported in the southeast. While the relative frequency of adult sized turtles is low in the Atlantic, it is not zero. In the Western Gulf and Eastern Gulf, the peak in relative frequency occurs in the 35 cm. size class, and in the Northern Gulf from the 25-35 cm. size classes. In all three sub-regions, the secondary peak occurs in the 60 cm. size class, which is considered the size class when adults are fully recruited into the reproductive portion of the population (Rene Marquez 1989, personal communication). The largest turtles were up to 80 cm. in estimated straight line carapace length.

To examine trends within each of the three life history stages, 5 cm. increments were used for relative frequency distributions to increase sample sizes. Least square linear regressions were applied to measure the significance of these trends and evaluate rates of increase or decrease within each stage. The natural log of each size class frequency was plotted v the mid-point of each 5 cm increment. Trends were defined by the slope (b)of the least squares linear regression applied. Results of this analysis by stage class are presented in figure xxx. In all cases, the relationship between frequency and size class was statistically significant even with such small, non-random sample sizes. Recruitment appears to be rapid to the 30 cm length or to the sub-adult stage ($r = .96$, $b = .26$). From the 30 cm. size class to 55 cm., the frequency of turtles declines ($r = .95$, $b = -.08$). Beyond 55 cm., the decline is more rapid ($r = .93$, $b = -.21$).

Frequency distributions of size class in 10 cm increments for the 225 turtles identified as female or male were developed within both the Gulf and Atlantic. In the Gulf, adults were routinely identified to sex. The extent to which sex was reported within the juvenile and sub-adult size classes is notable. Apparently, the relative emphasis on this species has resulted in considerable efforts at identifying sex (W. Teas personal communication, 1990) and as such these identifications are likely very reliable. This effort is a tribute to the network members and state coordinators.

Sex ratios were stratified by sub-region and season respectively (Table 1). When stratified by sub-region in addition to season, the sample sizes were too small estimate female to male ratios, except in the spring in the Western Gulf (2:1 $n = 56$) and in the fall in the northeast (1.5:1, $n = 67$). However, it is worth noting that all these ratios except in the spring in the Eastern Gulf (6:1, $n = 7$), and in the winter in the Western Gulf (1:1.8, $n = 11$) were from 1:1 to 3:1. These ratios stratified by season only ranged from 2:1 to 1:1.3: When stratified by sub-region only, ratios ranged from 1.1:1 to 3:1. Using all 225 turtles, the ratio was estimated as 1.6:1.

In 1980, Archie Carr (1980) forwarded a migration theory to explain the differential distribution of this species. In the most recent review by Pritchard (1989) on this species which includes a discussion on the zoogeography, there is no empirical resolution to the question of whether turtles outside the Gulf of Mexico are lost waifs or eventually recruited into the breeding population. Only through tag returns or the use of satellite tags will this definitive information be forthcoming. However, in the interim, the stranding data we have examined provide circumstantial insight into this question.

If the relative abundance of stranded turtles as reported to the STSSN, describe the differential size class distribution of this species within U.S. waters, it appears that most turtles were generally greater than 25-30 cm. in straight line carapace length. Proportionally more adults were reported from the Gulf of Mexico than the eastern seaboard of the Atlantic, however, adults were not excluded reported from the eastern seaboard. The disappearance of 55 to 60 cm turtles from the northeast, and the appearance of 60 to 65 cm turtles is curious and either a function of presence /absence, sampling bias, or differential mortality. In the southeast Atlantic, the distribution is nearly uniform from 35 to 55 cm., declines slowly through 65 cm. and terminates rapidly to 70 cm. This disappearance of adult sized turtles along the Atlantic coupled with the secondary peak in adult size turtles suggests that the secondary peak in the frequency of turtles of adult turtles suggests movement from the Atlantic into the Gulf of Mexico.

Assuming that those animals that wash-up on the coast utilize near shore habitat, suggests that at 25-30 cm. straight carapace length, turtles are fully recruited into these shallow coastal waters. Much of this habitat includes inshore waters (Carr 1980;

Lutcavage 1985; Pritchard 1989). If the disappearance of turtles of given size classes reflects mortality rather than differential sampling, then, the rate of decline through the adult stages was relatively rapid and the likelihood of an individual turtle participating in reproduction more than once is fairly low. Mortality on adult turtles in the Gulf of Mexico is relatively high.

These differential size distributions developed from the STSSN imply that 1) mortality on adults is lower in the Atlantic than the Gulf of Mexico, 2) the Atlantic has provided a reservoir of adults sufficient to keep this species from collapsing over the past ten years but not sufficient to reverse the decline observed on the nesting beach and 3) if mortality on adults were appreciably reduced in the Gulf of Mexico, the outlook for species recovery is quite positive.

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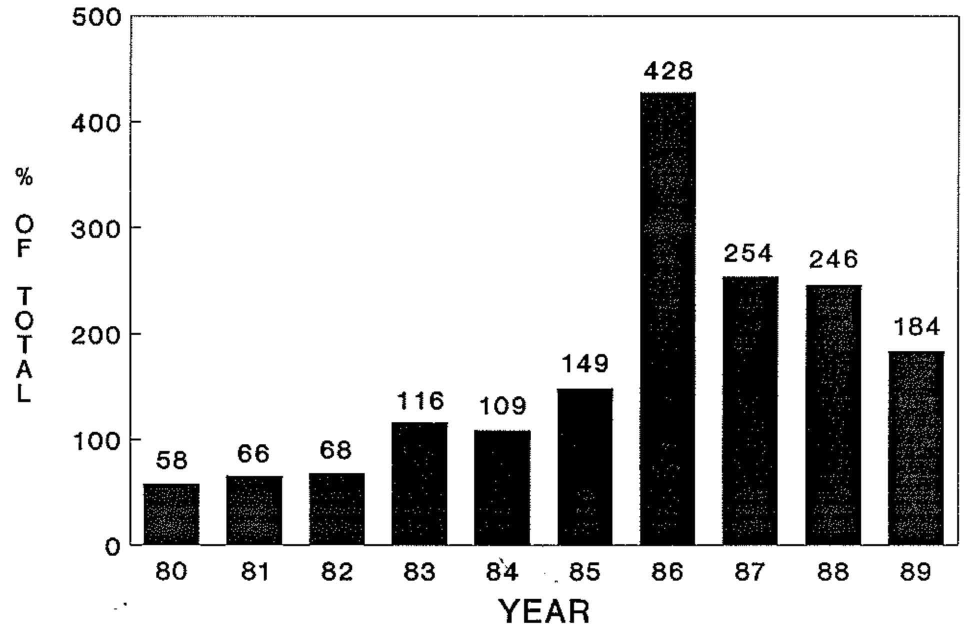
List of Figures and Tables



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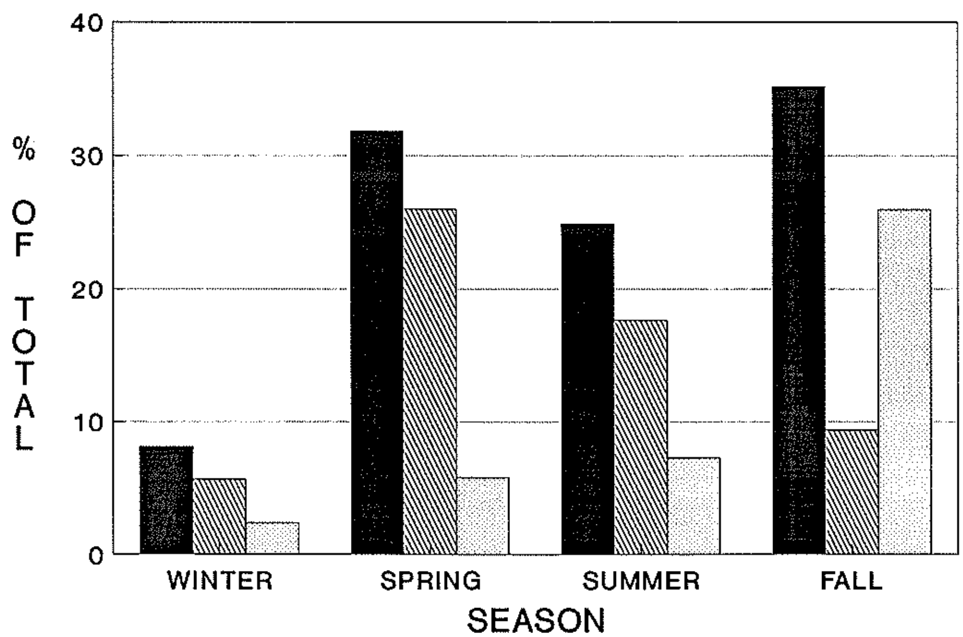

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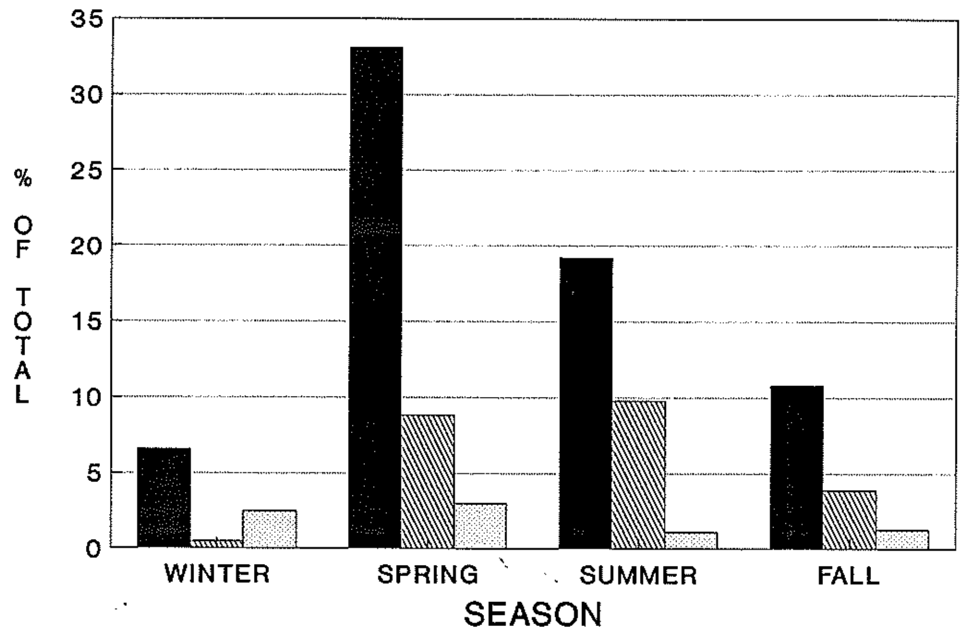
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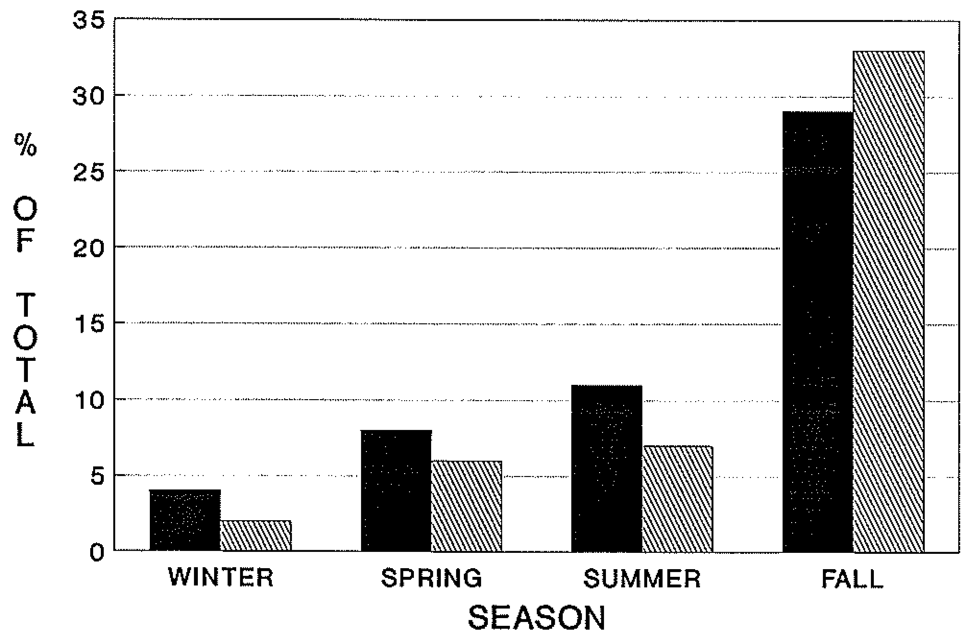
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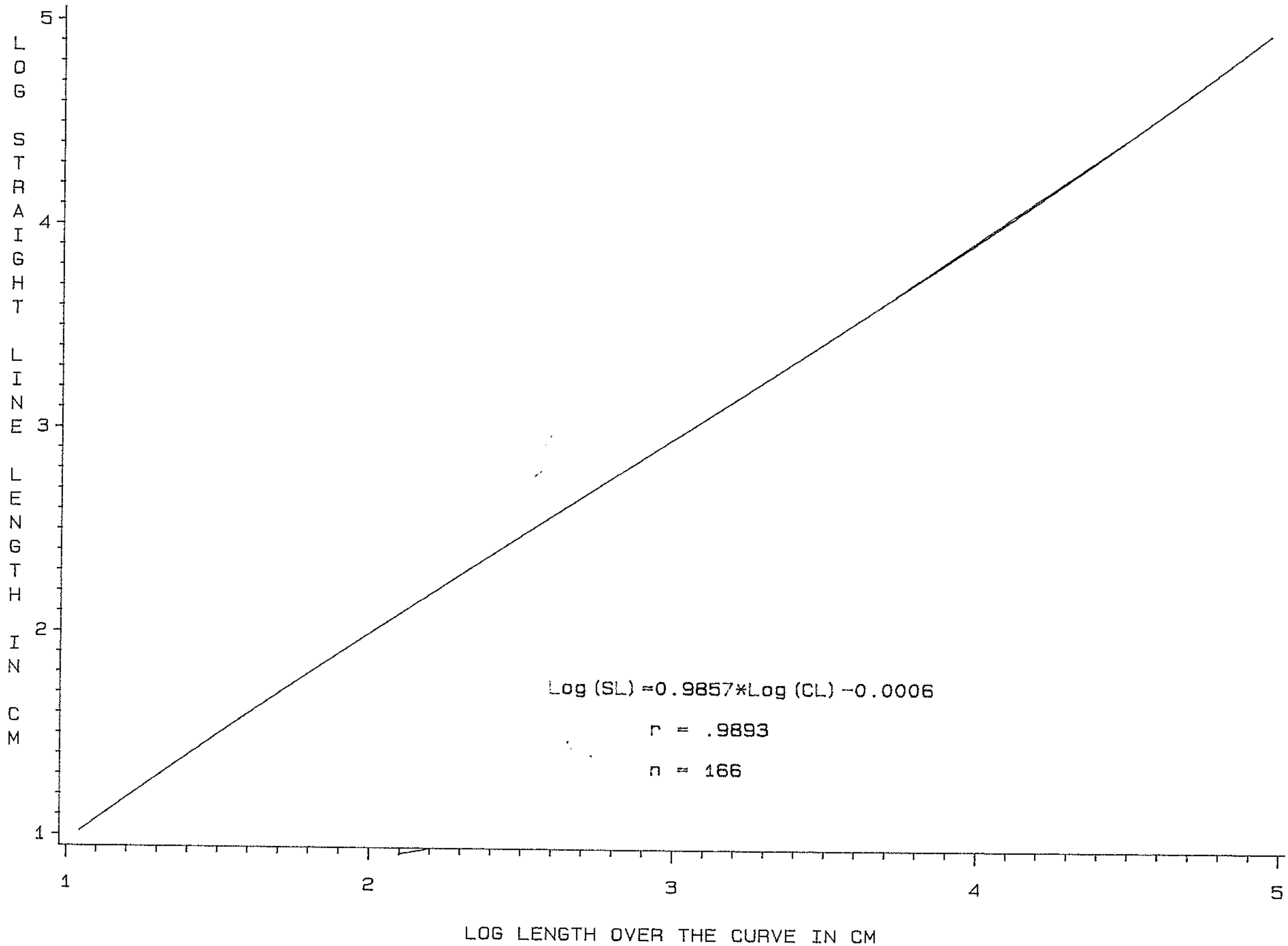
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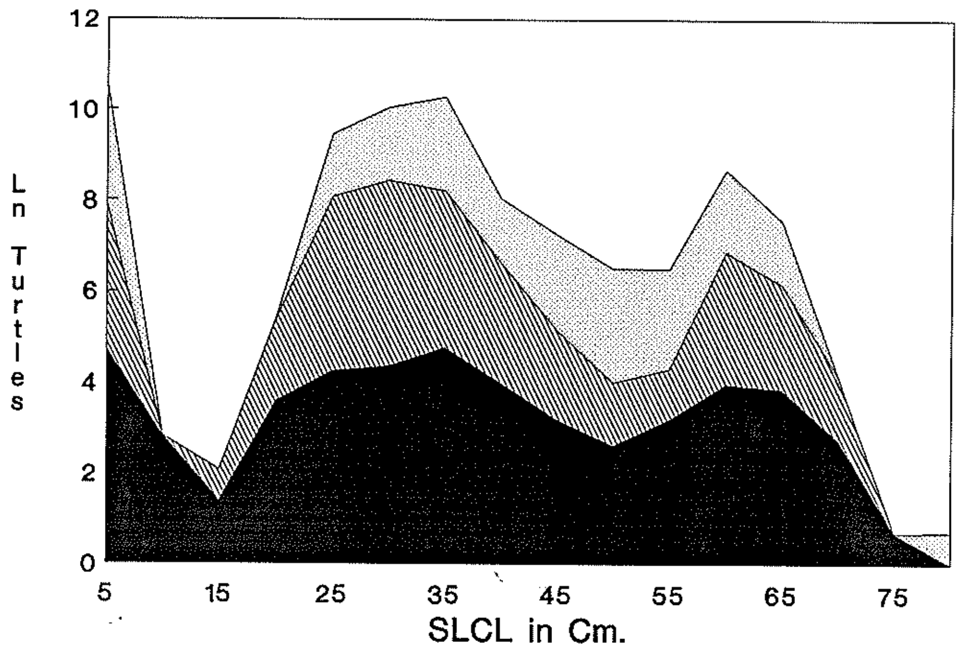
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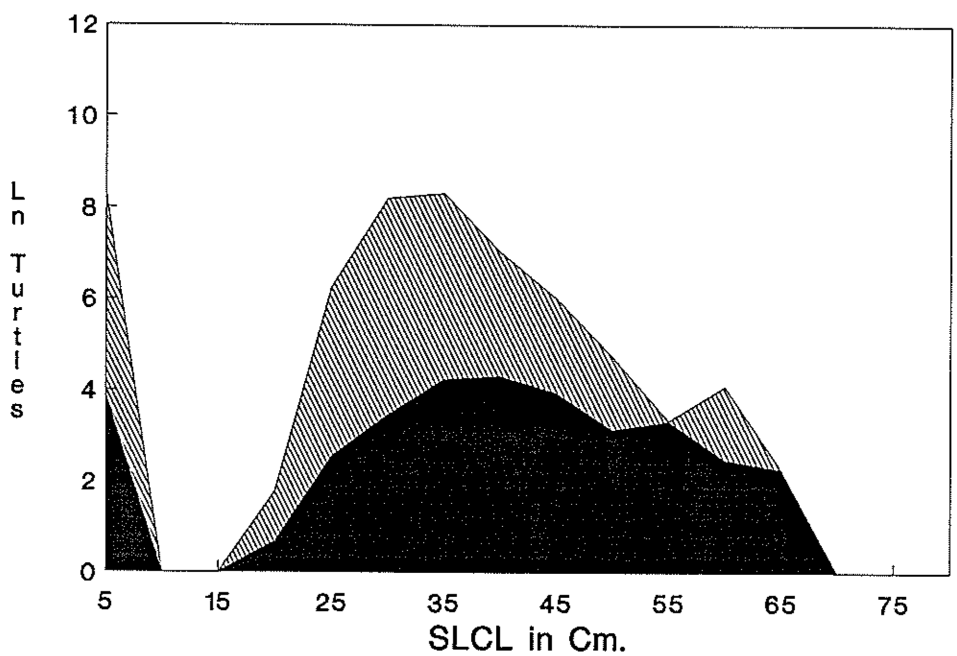
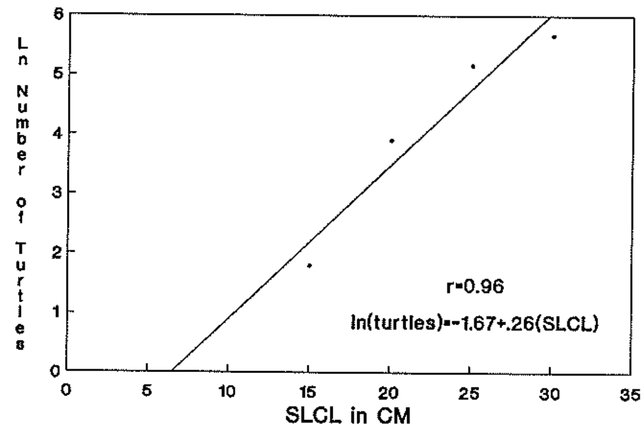
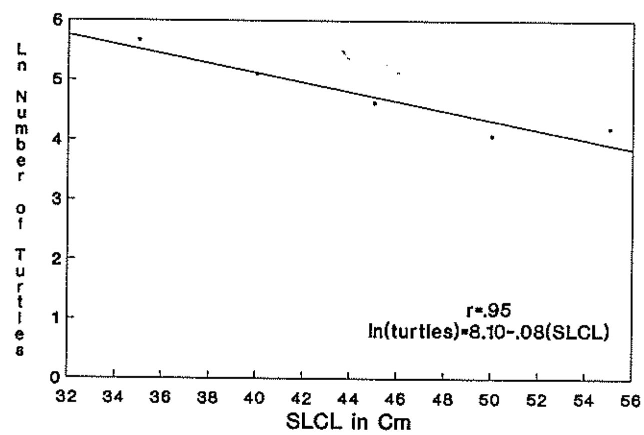
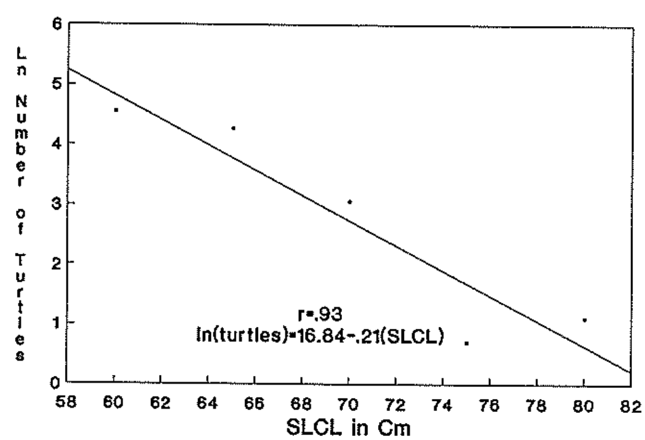
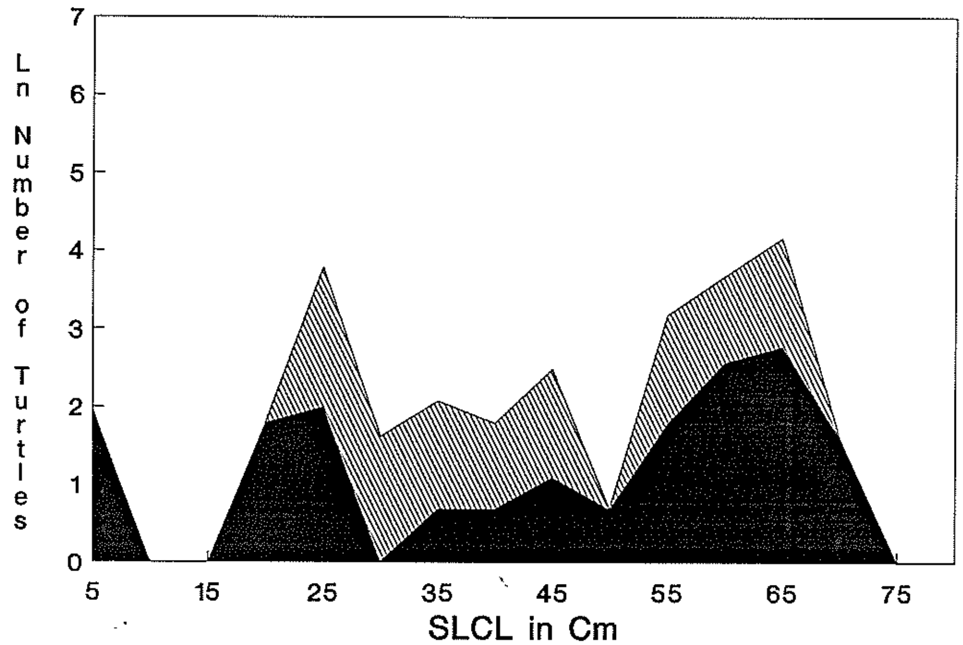
75
SLCL in Cm.


12
10
8
6
4
2
0
L n Turtles
5
15
25
35
45
55
65
75
SLCL in Cm.

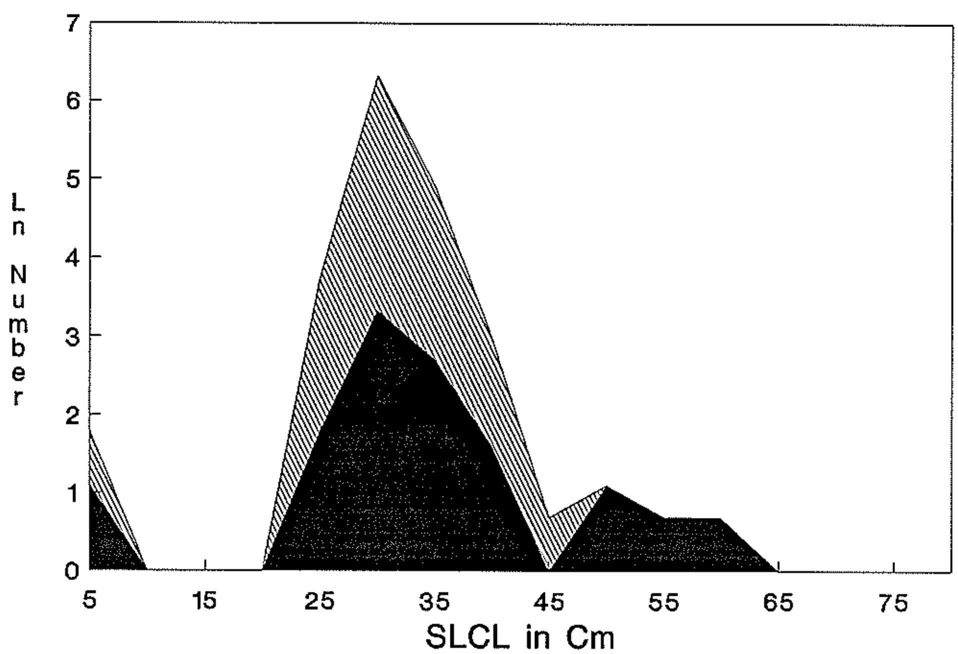

Ln Number of Turtles
SLCL in CM
r=0.96
ln(turtles)=-1.67+.26(SLCL)


Ln Number of Turtles
SLCL in Cm
r=.95
ln(turtles)=8.10-.08(SLCL)


Ln Number of Turtles
SLCL in Cm
r=.93
ln(turtles)=16.84-.21(SLCL)



Ln Number of Turtles
7
6
5
4
3
2
1
0
5
15
25
35
45
55
65
75
SLCL in Cm



Ln Number
7
6
5
4
3
2
1
0
5
15
25
35
45
55
65
75
SLCL in Cm

Table 1. Computed ratio of female to male turtles stratified by season and sub-region. Sub-regions in the Gulf of Mexico include: WG=Western Gulf; NG=Northern Gulf; EG=Eastern Gulf; SE=Southeastern Atlantic; NE=Northeastern Atlantic. Ratios were also computed over all regions for each season and for each season over all sub-regions.

	WG	NG	EG	SE	NE	ALL
WINTER	1:1.8 (11)	0 (0)	3:1 (4)	1:1 (2)	0:1 (1)	1:1.3 (18)
SPRING	2:1 (56)	2:0 (2)	6:1 (7)	2:3 (5)	3:0 (3)	2:1 (73)
SUMMER	3:1 (19)	0 (0)	1:1 (2)	3:1 (4)	1.3:1 (7)	2:1 (32)
FALL	1:1 (10)	1:0 (1)	2:1 (3)	1.1:1 (21)	1.5:1 (67)	1.4:1 (102)
ALL	1.6:1 (96)	3:0 (0)	3:1 (16)	1.1:1 (32)	1.5:1 (78)	1.6:1 (225)